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Toward full result for NLO dijet production in proton-nucleus collisions

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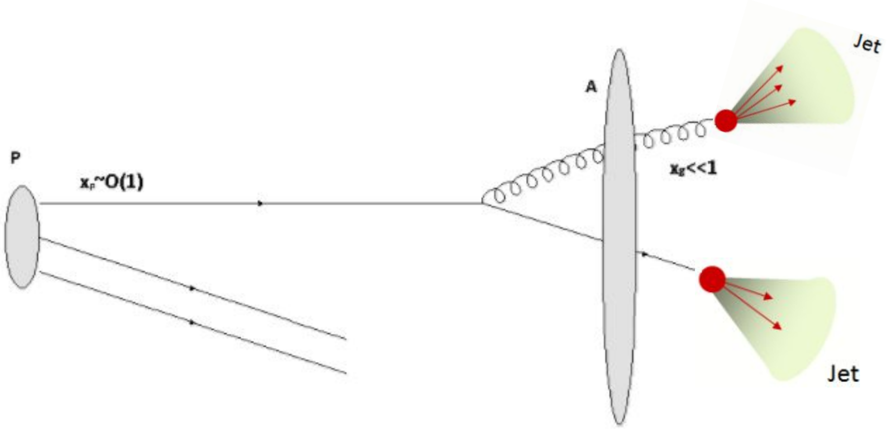
Forward Jet Production

The basic setup: a large-x parton from the proton scatters off the small-x gluon distribution in the target nucleus. The large-x parton is most likely a quark.
We adopt the formalism of the LC outgoing state, using the CGC effective theory together with the hybrid factorization.

The LO result appears in hep-ph/0708.0231 (C. Marquet).



Quark fragmentation in the presence of a shockwave.

The LO Forward Dijet Cross Section

Then the result for the leading-order dijet cross section is given by (at large N_c):

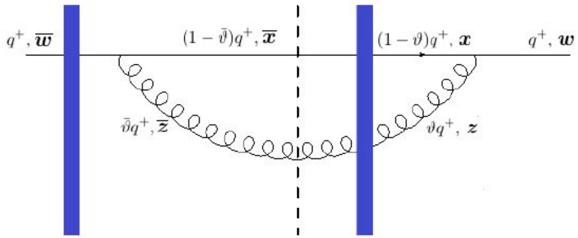
$$\frac{d\sigma_{\rm LO}^{qA\to qg+X}}{dk^+\,d^2\boldsymbol{k}\,dp^+\,d^2\boldsymbol{p}} = \frac{2\alpha_s C_F}{(2\pi)^6\,q^+}\frac{\left(1+(1-\vartheta)^2\right)}{\vartheta}\delta(q^+-k^+-p^+)$$
$$\times\int_{\boldsymbol{x},\,\overline{\boldsymbol{x}},\,\boldsymbol{z},\,\overline{\boldsymbol{z}}}\frac{\boldsymbol{X}\cdot\overline{\boldsymbol{X}}}{\boldsymbol{X}^2\,\overline{\boldsymbol{X}}^2}\,e^{-i\boldsymbol{p}\cdot(\boldsymbol{x}-\overline{\boldsymbol{x}})-i\boldsymbol{k}\cdot(\boldsymbol{z}-\overline{\boldsymbol{z}})}$$
$$\times\left[\mathcal{Q}(\boldsymbol{x},\,\boldsymbol{z},\,\overline{\boldsymbol{z}},\,\overline{\boldsymbol{x}})\,\mathcal{S}(\boldsymbol{z},\,\overline{\boldsymbol{z}})-\mathcal{S}(\boldsymbol{x},\,\boldsymbol{z})\,\mathcal{S}(\boldsymbol{z},\,\overline{\boldsymbol{w}})-\mathcal{S}(\boldsymbol{w},\,\overline{\boldsymbol{z}})\,\mathcal{S}(\overline{\boldsymbol{z}},\,\overline{\boldsymbol{x}})+\mathcal{S}\,(\boldsymbol{w},\,\overline{\boldsymbol{w}})\right]$$

The dipole and quadropole are defined by:

$$\mathcal{S}\,(\overline{\boldsymbol{w}},\,\boldsymbol{w}) \equiv \frac{1}{N_c}\,\mathrm{tr}\left[V^\dagger(\overline{\boldsymbol{w}})\,V(\boldsymbol{w})\right]$$

$$\mathcal{Q}\,(\overline{\boldsymbol{x}},\,\boldsymbol{x},\,\boldsymbol{z},\,\overline{\boldsymbol{z}}) \equiv \frac{1}{N_c}\,\mathrm{tr}\left[V^\dagger(\overline{\boldsymbol{x}})\,V(\boldsymbol{x})\,V^\dagger(\boldsymbol{z})\,V(\overline{\boldsymbol{z}})\right]$$

Example for a contribution:



From the partonic cross section we can find the quark channel contribution by convolution with the PDF:

$$\left.\frac{d\sigma_{\rm LO}^{pA\to 2jet+X}}{d^3p\,d^3k}\right|_{q-channel} = \int dx_p\,q_f(x_p,\mu^2)\frac{d\sigma_{\rm LO}^{qA\to qg+X}}{d^3p\,d^3k}$$

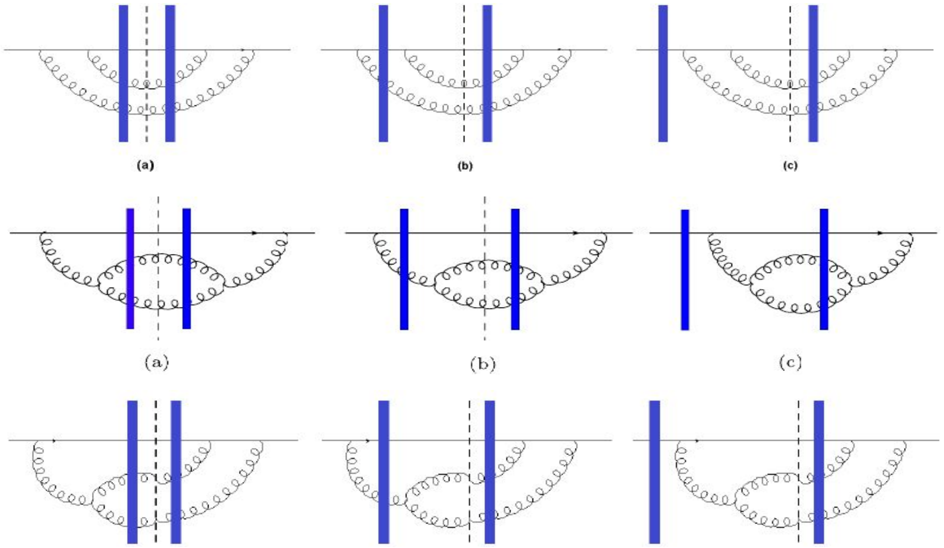
The Trijet Setup

Two possible configurations of 3 particles in the final state:

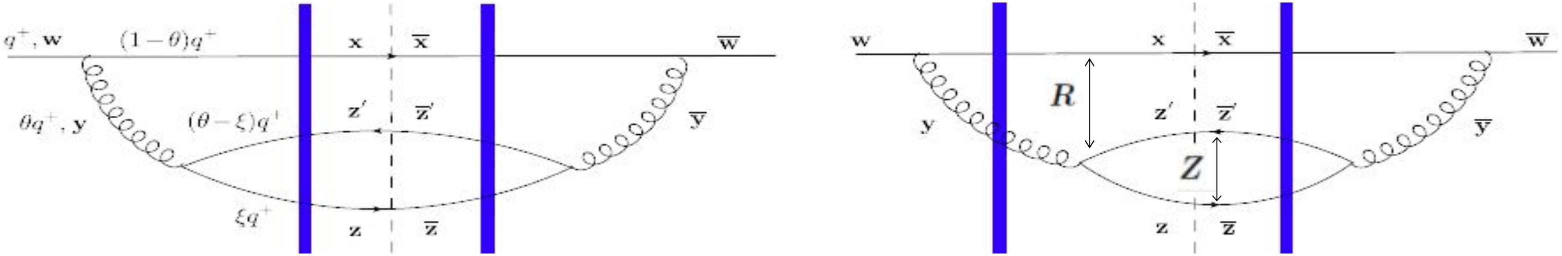
a) ***Quark, quark and anti-quark***,

b) ***Quark together with two gluons***.

The production of these configurations happen via two successive parton splittings (in the light-cone formalism, there are also 1->3 instantaneous vertices).



The quark quark anti-quark Trijet



$$\frac{d\sigma^{qA\to qq\overline{q}+X}}{dk_1^+\,d^2k_1\,dk_2^+\,d^2k_2\,dk_3^+\,d^2k_3}=\frac{\alpha_s^2\,C_F\,N_f}{2(2\pi)^{10}(q^+)^2}\,\delta(q^+-k_1^+-k_2^+-k_3^+)$$

$$\times\int_{\overline{x},\overline{z},\overline{z}',x,z,z'} e^{-ik_1\cdot(x-\overline{x})-ik_2\cdot(z-\overline{z})-ik_3\cdot(z'-\overline{z}')}\,\frac{R^i\,Z^j\,\overline{R}^m\,\overline{Z}^n}{Z^2\,\overline{Z}^2}$$

$$\times\Big[\mathcal{K}_0^{ijmn}(x,\,z,\,z',\,\overline{x},\,\overline{z},\,\overline{z}',\,\vartheta,\,\xi)\,\mathcal{W}_0\,(x,\,z,\,z',\,\overline{x},\,\overline{z},\,\overline{z}')$$

$$-\,(z,\,z'\to y)\,-\,(\overline{z},\,\overline{z}'\to\overline{y})\,+\,(z,\,z'\to y\;\&\;\overline{z},\,\overline{z}'\to\overline{y})\Big]+(k_1^+\leftrightarrow k_2^+,\,k_1\leftrightarrow k_2).$$

At large Nc:

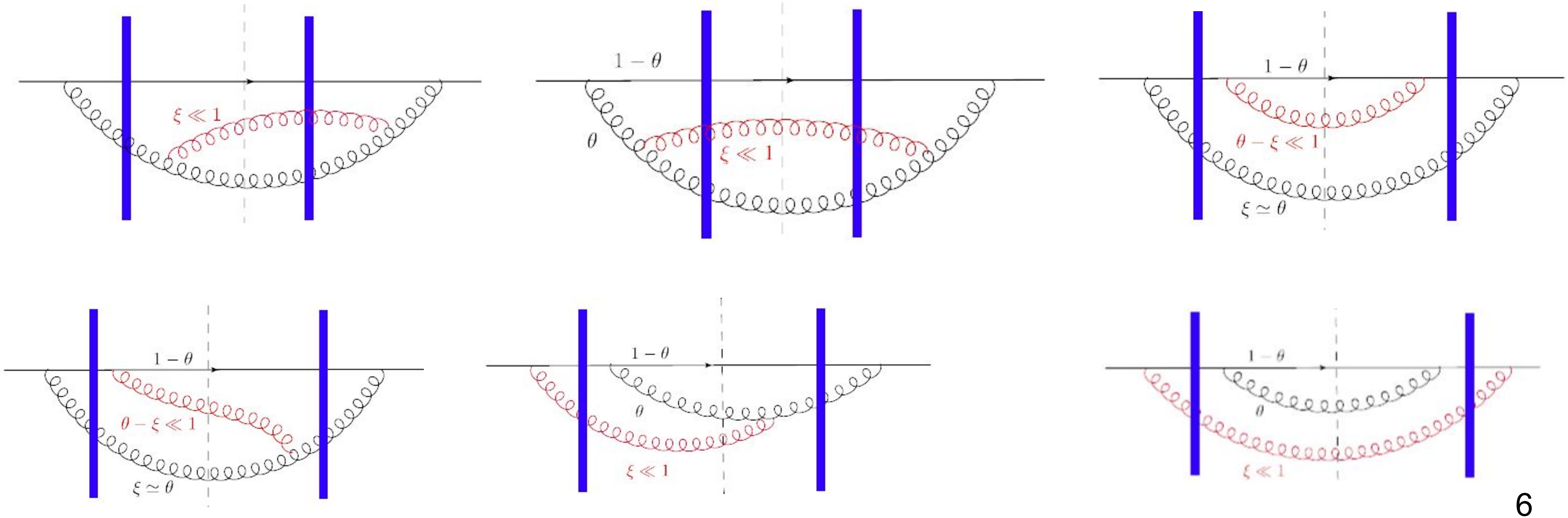
$$\mathcal{W}_0\,(x,\,z,\,z',\,\overline{x},\,\overline{z},\,\overline{z}')\simeq\mathcal{Q}(x,\,z',\,\overline{z}',\,\overline{x})\,\mathcal{S}(z,\,\overline{z})-\mathcal{S}(z,\,\overline{w})\,\mathcal{S}(x,\,z')-\mathcal{S}(w,\,\overline{z})\,\mathcal{S}(\overline{z}',\overline{x})+\mathcal{S}\,(w,\,\overline{w})$$

$$\mathcal{K}_0^{ijmn}(x,\,z,\,z',\,\overline{x},\,\overline{z},\,\overline{z}',\,\vartheta,\,\xi)\equiv\frac{\Phi^{ij}_{\lambda_3\lambda_2\lambda_1\lambda}(x,\,z,\,z',\,\vartheta,\,\xi)\,\Phi^{mn\,*}_{\lambda_3\lambda_2\lambda_1\lambda}(\overline{x},\,\overline{z},\,\overline{z}',\,\vartheta,\,\xi)}{[\vartheta^2(1-\vartheta)R^2+\xi(\vartheta-\xi)Z^2]\,[\vartheta^2(1-\vartheta)\overline{R}^2+\xi(\vartheta-\xi)\overline{Z}^2]}$$

The effective vertex contain the information about both the reg. and inst. interactions.

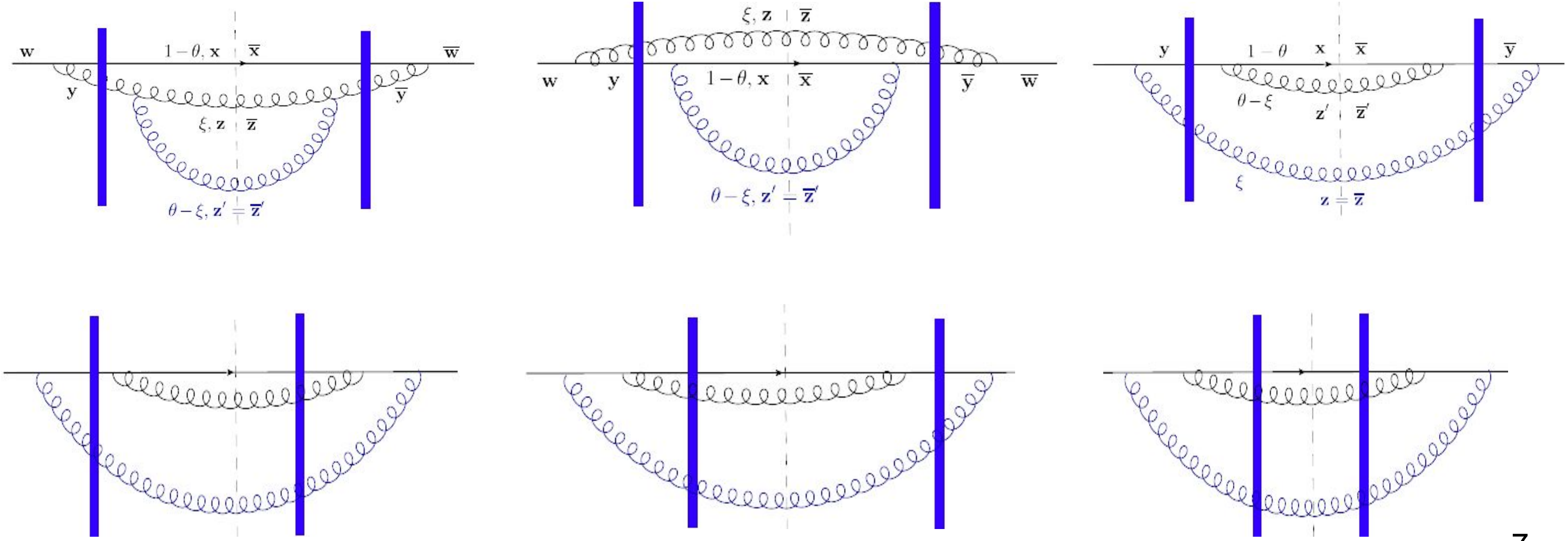
Recovering the B-JIMWLK Evolution

In the limit when one of the gluons become soft (eikonal emission vertex = no recoil of the emitter), the general NLO result has to reduce to one step in the real part of B-JIMWLK evolution of the leading order dijet production result. We managed to show that this is indeed the case in our result.



Recovering the Real DGLAP Evolution

In the collinear limit, when the separation between partons become arbitrarily large, we recover the DGLAP evolution of the initial / final quark state distribution.



Summary

1) We computed the NLO dijet production cross section of an incoming quark.

2) Short-distance poles has been shown to cancel between pairs of diagrams.

3) Full match has been established between the eikonal limit of the result and the action of JIMWLK acting on the LO cross section for forward dijet production.

4) Full match has been established with DGLAP evolution in the collinear limit.